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some error in the mode of conducting the examination. It appears, however, that the rotation of fluids in closed sacs or tubes has not as yet been more extensively observed. The circulation described by M. Schultz would certainly be a closer analogy to the motions of fluids in animals than we could, from other circumstances, suppose to exist.

No. XIV.

PLANING MACHINE.

An application was made, during the last session, on the part of the Society, to Mr. Joseph Clement, Prospect Place, Newington Butts, for liberty to publish in the Transactions, a full description of the Planing Machine recently set up by him in his manufactory. The requested permission was granted, without hesitation, by that very liberal and ingenious artist; and Mr. C. Varley was commissioned by the Society to make the drawings, and to prepare a description of the same, fully adequate to the complete illustration of this beautiful machine. The scale of the principal figures in Plate VIII. is three-tenths of an inch to a foot, and of those in Plates IX. and X. one inch to a foot.

The engineers' planing machine is used to cut metal, so as to produce clean and perfectly straight or flat surfaces. It differs greatly from the carpenter's tool called a plane, the length and straightness of which prevent the cutter from descending into any hollows; it therefore gradually removes the prominences, and the cutter is never allowed to project through deeper than the thickness of the shaving which the workman can safely take off without tearing up the grain of the wood. The wider such a plane is the flatter will it work; but, as the resistance increases with the width of the cutter, this latter rarely exceeds two inches, or two and a half; for beyond that the weight and strength of a man are scarcely sufficient to overcome the resistance.

The planing machine about to be described bears more analogy to the turning lathe; it performs its work in right lines, and is so constructed that during longitudinal cuts the tool is stationary and the work moves, but during lateral cuts the tool moves. The tools or cutters are similar to those used at the lathe, their forms being in like manner varied, from a strong point to a chisel-shaped edge to finish the work. In the lathe, a mandril, supported in immovable collars, presents the work to the tool in the firmest manner, and with the least possible friction.

Mr. Clement, with a view to remove as far as possible the friction and labour, causes the bed of his machine, on which the work is laid, to pass under the cutting tools on perfectly true rollers or wheels, which are lodged and held in their bearings as accurately as the best mandril could be, and having set-screws acting against their ends, which totally prevents all end-motion, and by which they are perfectly adjusted in that direction. He also saves or uses the whole time by making cuts both ways, there being two cutters mounted; one to cut while going, the other when returning.

Having succeeded, in the contrivance of his machine, to reduce the friction or labour of moving it probably to a minimum, the next object of Mr. Clement was to meet the tool, and also the work, in every part where there could be any room or tendency in them to move or spring away from each other, with such full and efficient support as effectually to destroy all tendency to vibration, and thereby obtain full, sound, and quiet cuts.

For this purpose it was requisite to obtain a very perfect base to build on, one that would not bend, spring, or yield in any way to the most unequal loads that were liable to be put on it; and, as a rock exceeds all others for this purpose, Mr. Clement began by laying in the earth an artificial rock, or bed of masonry, with an iron surface large enough to give confidence in the superstructure.

In Plate VIII., fig. 1 is a plan of the surface, and fig. 2 a section of this artificial rock. *a a* is the iron surface level with the earth, or with a floor laid on the earth; it is 19 feet long by 4½ wide, and is cast whole, with under ribs or bars six inches deep to strengthen it. The depth of brick-work is three feet, and below the middle of it there is a stone *b b*, six inches thick and five feet square; it is perforated with twelve holes, in which twelve bolts *c c* are put, with their heads and collars underneath; there are eight more bolts with as many separate stones *b b*. These being held perpendicular by the surface plate *a a*, which was suspended over them quite level, had the *brick-work* built in amongst them with *cement*, so as perfectly to fill every space. This solid pier was brought almost to touch the iron surface; and whilst the latter was ascertained to be quite level, the remaining space was very perfectly filled in with cement. Thus the whole was united together as one solid mass. Semicircular cavities were left, and made quite smooth, to receive the lower portion of the wheels; these cavities are deeper than the wheels, to prevent any thing that might fall in from touching them, and their smoothness enables them to be swept clean. Boards *d d* are also fitted over these cavities to prevent, as much as possible, things getting in. *e e* the bearings of the wheels *f f*.

Fig. 3 shews the two feet of the upright standards cut off at the dotted line 78, fig. 1, Plate IX.; they have twelve holes that fit on the bolts *c c*, by which with screwed nuts they are made fast to the base; these feet meet each other under the middle of the machine.

Fig. 4 is a top view of the iron bed *k*, on which the work is laid; it has strong longitudinal and crossing bars, and is cast whole: *g g* the ends of two of the bars that serve for inverted iron rails; they are made perfectly straight and parallel, to lie on the wheels *f f*, and fit perfectly between their outer rims. The tops of all the wheels are strictly of the same height, so that the bed *k k* rests equally on them all, and is always truly horizontal or level: *h h* the ends of two racks; they are screwed to the under side of the bed, and engage the pinions *i i*, fig. 1, from which the bed receives its motion: *j* the wheel that communicates with the moving power.

In Plate IX., fig. 1 is a side elevation, and in Plate X., fig. 1 is a front elevation of the machine, the latter shewing how the perfectly parallel bars or rails *g g* lie upon and fit without any shake or spare room between the rims of each pair of wheels *f f*. These wheels are therefore made very strong, and are united by very strong axes; their form and strength are such, and the fittings in their bearings so good, as to prevent all lateral spring or yielding of the bed *k*. *l l l l*, fig. 1, Plate VIII., end views of six bars or ridges that are cast crossways under the bed to strengthen it; a view of the end one of these bars is shewn fig. 1, Plate X. The dotted lines *m m* in the last figure shew the two middle longitudinal bars, which, with the outer bars or rails *g g*, render the bed sufficiently strong in that direction. *n n* two strictly upright standards, whose large feet are secured to the base by the twelve screw-bolts *c c* before mentioned : their front and back faces are planed quite parallel to each other, and the faces of the two standards are parallel with each other, and are set in a line perfectly at right angles with the line of the bed's motion, and their upright perforations are planed strictly true; so that by the turning of the long screws within them, the vertical sliding carriages *o*, Plate IX., and *p p*, Plate X., may be simultaneously raised or lowered. To the bottom of one of these standards *n* is attached part of the apparatus for alternating the motion of the bed *k*.

I now proceed to describe how the motions of the machine, both direct and alternating, are given. In Plate IX., fig. 1, *q* is one of the winch-handles by which the axis *r* is turned; *s* and *t* two bevel-wheels loose or free to turn ont he axis *r*, and always in gear with the bevel-wheel *u*. Fig. 2 is a top view (twice as large) of these bevel-wheels in section; the bevel-wheel *u* is also free to turn on its axis *v*. On the axis *r*, between the wheels *s* and *t*, is placed a barrel or double clutch, which can slide from one wheel to the other, but cannot turn on the axis, it being prevented by a rib or fin *w*, as shewn in fig. 3. This barrel has four radial bars at each end *x x*, and the wheels *s t* have corresponding bars; therefore, to whichever wheel it is slid, it engages the bars and carries that wheel round, which in its turn becomes the driver of the wheel *u*, but this wheel is not fast to its axis; therefore it is made in the first instance to carry its axis round only by friction, for which purpose its axis *v* has a flanch *y* on it, to which is fixed by three screws a conical-rimmed wheel *zz* : this cone fits well into the conical back of the bevel-wheel *u* ; and on the other side of this wheel, fitting close within its teeth, is a flat-rimmed flanch 1, also fitted well, by an hexagonal hole, on the axis *v*, so as not to turn round: this is urged close by a strong screw 2, so as to pinch the wheel *u* between itself and the conical rim *z* so tight, that the wheel *u* can carry round the axis *v* by its friction between the two rims *z* and 1. This friction is not left to be the only carrying force, for when it is not enough, the wheel *u* slips round nearly one turn, and then a stud 3, which is screwed into it, comes in contact with a bar in the flanch *z*, and obliges it to go round, (the use of this provision will be shewn farther on). In fig. 1 is shewn a band-wheel 4; it is fitted on the farthest end of the axis *v*; it is therefore carried round by the wheel *u*. 5 5 is the leather band which gives motion to the wheel *j*; it is a double band, one lying on the other, by which its friction or hold of the two wheels is much increased. 6 is a lever turning on the fulcrum 7; by its forked top the clutch *x x* may be moved from one wheel to the other. The arrows shew the direction in which the bed *k* is now moving, and when it has gone far enough to carry the work that may be laid on it past the cutter, the bottom end of the lever 6 will require to be pushed to its dotted place to alter the gear, and thereby make the bed *k* return. In order to suit any length of work, a series of holes 8 8 is made all along the side of the bed *k*; they are six inches apart: by these the sliding plates 9 9 and 10 10 may be fixed to exactly the right part; from these plates project the studs 11 and 12. When the bed has gone far enough, the stud 11 will come against a lever 13, partly seen by dotted lines, and push it over to the position shewn in the separate view, fig. 4. To this lever are jointed the two long slender rods 14 and 15, eight inches apart; their other ends are jointed four inches apart to a lever on an axis 16; and on the same axis is fixed the arm

17; therefore, when the lever 13 is pushed to the left, the arm 17 is carried over to the left, as shewn by dotted lines, and carries with it the lever 6, which alters the gear, so that the same motion of the power will cause a return of the bed *k*. To assist in this change, and make it certain that the gearing arms *x x* shall lay hold of those in the wheel, there is a tumbler 18, which is an iron ball screwed tight on the rod 19, at any suitable place: this tumbler rod 19 is on the same axis with the arm 17, and is therefore alternately raised by the rods 14 and 15. The weight of the tumbler will be against the lever 6 till the clutches have laid hold; consequently it obliges them to take hold; but when they are in gear the ball 18 rests against a stop, and only keeps the gearing safe; thus removing all friction of the fork 6 from the clutch *x x*. The tumbler is most necessary when the machine is moving slow. There are three provisions to assist in alternating so heavy a mass as the bed *k* and its work, by which all shock is not only prevented, but the very momentum is made use of to cause an easy return. In fig. 4, above the lever 13, are shewn two spring detents. Fig. 5 is a top view of them; these have notches to hold the lever 13 on either side, so that the lever cannot be moved till the detent which holds it is raised; on this account the stud 11, fig. 1, is so placed that it can raise the detent; but to each side of the lever 13 is fixed a strong spring 20 20, (these would fly out much wider, but are held in by the iron loop 21, fig. 4). Now, the stud 11 cannot raise the detent till it is very near to the lever 13; therefore it comes in contact with the spring 20 first, and winds it up by pressing it close to the lever. The stud then raises the detent and liberates the lever; and as it proceeds to urge forwards the lever 13, the spring assists in raising and throwing over the tumbler 18; but if raising the tumbler had discharged the gear, there would remain no action to secure its going into gear on the opposite side; therefore the arm 17 only lays hold of the lever 6, by a loop sufficiently wide to let the tumbler be raised, without affecting the gear, while the power continues to carry forwards the bed, and with it the lever 13, till the tumbler is raised; then the spring 20 at the lever 13 throws the tumbler over: the lever 13 is then caught in the notch of the opposite detent, as shewn in fig. 4. Till now, the screw-stud 3, fig. 2, was the absolute driver in case of need, which forced round the axis *v*; but it was stated above that the friction of the wheel *u*, between the two flanches *z* and 1, is just sufficient to move the machine. Now, as the momentum of the bed has a tendency to carry round the axis *v* in the direction in which it was formerly driven, or at least to counteract the power that should return it, and, for a moment, stand still, the friction of the wheel *u* becomes of the greatest use, for it would be a great loss to check the moving power which is accumulated in the fly-wheel 22; and the shock often repeated would tend to destroy the wheels; but now there is nothing except the friction of the wheel *u* to carry back the machine; therefore the moving power goes on till this friction has gradually overcome the inertia, or till the driving stud 3 has made nearly one revolution, and got to the other side of the bar, by which it will force a return; here this one turn of friction is sufficient to prevent all shock. We must now return to the lever 13, for here let the momentum of the bed be what it will, the stud 11 cannot pass the lever 13 without breaking it, and on this account the strong springs 20 are needful to receive the momentum of the bed, and not let it come with a shock against the lever. That momentum is, therefore, one gage for their strength, and they do receive the momentum and give it back in aid of the return so accurately, that the bed goes to the end perfectly quiet, and returns so immediately as to remove all sense of its weight, and the man at the winch-handle neither hears nor feels the return. Thus, the friction of the wheel *u*, and the springs 20, perform a most important service in continually alternating so very heavy a mass. Of course, it will be seen that the stud 12, which is adjusted to suit the other end of the work, causes the contrary alternation in exactly the same manner.

The next action in order is moving the tool, so as to bring it to the best place for doing its work; and secondly, to withdraw it during each return. It was stated above, that the long screws within the standards, Plate X. fig. 1, *n n*, are for the purpose of raising or lowering and holding the carriages *p p*. These screws have flanches near their upper ends, which are let into recesses made in the top of the standards *n n*, as shewn in the section fig. 2. These flanches are somewhat thicker than the recesses are deep, and are covered by circular collars 23, which are held down by three screws tight enough to prevent all end-shake or rising of the screws. On the top of the screws are fixed the bevel-wheels 24 24, fig. 1: these are moved by the pinions 25 25, which have a wheel 26, and handle 27 for that purpose; and in order to place the two pinions close to their bearings, the long screws are made right and left, that they may still act together. The standards are correctly held apart at top by the strong flanched and hollow cylinder 28; they are then, with the pinion-bearings, all bound firmly together by a strong bolt, which passes through them and the screwed nuts 29 29. This bolt is shewn separate in fig. 3: it is enlarged at each end, with holes for the long screws to pass through. The section, fig. 2, shews them thus held together. Fig. 4 is a horizontal section of a standard, to shew a top view of the right carriage *o p*. Fig. 5 is an inside view of the same carriage. The middle of these carriages is perforated to make room for screwed nuts, which are drawn sufficiently tight by screws 30 30, to prevent all loss of time or end-shake which might occur from the long screws wearing loose in their holes: 31 is one of the bearings for the heavy, flat slide-bar 32, fig. 1. This bar has circular bearings to allow it to oscillate a few degrees. In figs. 4 and 5, 33 34 are stops or screws to adjust and limit the motion of the bar 32, or they fix it from moving when so required. They have binding screws 35 35.

In Plate IX., fig. 6 shews a section of the bar 32, with a strong arm or stud 36, projecting downwards between the stops 33 34: (in this figure 33 is omitted). It would be best for these studs to be solid with the bar; but for some particular uses of the machine it is necessary to remove them, and it was more convenient to make and perfect the bar without them; therefore they are very tightly screwed in, and then secured by two more screws, as shewn in fig. 7. There is one at each end of the slide-bar 32, and their stops are adjusted to act simultaneously. On the left side of fig. 1, Plate X., the bar 32 projects through its bearing, and has an arm 37 screwed to it by a broad saddle-piece that fits against it. It must now be stated, that the axis of the middle pair of wheels *f*, the axis of the lever 13, and the axis of the strong bar 32, are purposely placed one above the other; and the axis of the lever 13 projects through the standard sufficiently to receive a pipe or barrel 38, from the inner end of which also projects an arm 39 to correspond with the upper arm 37; and as the lever 13 is the medium through which all the alternations are produced, its arm 39 is joined to the upper arm 37 by a connecting rod 40; and to allow the bar 32 to be varied in height, and yet keep the connexion, this rod is long and passes through a hole in a swivel on the arm 37, and is bound at the right place by a screw; therefore, when this connexion is made, every alternation of the lever 13 produces a corresponding change in the position of the strong slide-bar 32. This slide-bar is one inch thicker at bottom than at top, and is made quite flat and true on all its four sides, to receive on it the sliding carriage 41 41: this carriage is made of four plates fitting accurately around it. The bar 32 is also perforated its whole length to receive a screw to move the carriage, the back plate of which has two similar dovetails, shewn in fig. 6, Plate X., for the purpose of receiving towards either end the vertical slide-rest or tool-holder 42, fig. 1. The front plate (see fig. 1) has two circles of screwed holes, by which the circular plate 43 may be attached at either end; on it is a dovetail to receive the slide-rest 44. Fig. 6, Plate X., is a top view of the sliding carriage 41, to shew the three dovetails. The bed *k* is moving the same way in Plates IX. and X.; therefore the front tool 45 is down and making a cut; but when the alternation is made by the lever 13 going to the left, as in fig. 4, Plate IX., the connecting rod 40 will move the bar 32, and lift that cutter off the work, as shewn in fig. 6, Plate IX. If this cutter only was used, the work would then have to return, and this cutter must again come down to make a second cut; but as there are two cutters mounted, the back cutter 46 will be brought down to make a cut during the return: the cutters of course require to be so placed as to be laterally, at least one cut apart, and to move twice as far, or the distance of two cuts, for each repetition if they were to cut in the same plane; but it is preferable to place them three or four cuts apart, and to set the second tool one cut deeper than the other, so that two surfaces are removed, one by each cutter, then no nicety of adjustment is required. This lateral motion is also produced by the axis of the lever 13; for the long horizontal screw, of two and a half threads in the inch, which passes through the slide-bar, has a wheel 47 of 200 teeth fixed on it; and below, under one side of the wheel, is a frame 48 carrying a short axis with a pinion; a top view of which is shewn in fig. 5, Plate IX., and a side view separate in fig. 8. On the end of this pinion-axis is fixed a cross-bar 49, with square holes along each arm. On the outer end of the barrel 38 that is fixed on the axis of 13, is another arm 50, with a rack or short segment of teeth at its end; this engages the pinion; and they are so proportioned as that at each alternation the pinion and its arms 49 move about 120° to and fro. Into one of the square holes of one arm 49 is fixed a swivel-stud, from which proceeds a second long connecting rod 51; this is bound by a screw into a swivel-hole at the back of a loose arm 52, placed at the inner side of the wheel 47. At the end of this arm is placed a spring-catch, which may be turned either way, so as to lift up that side of the wheel 47, or to pull it down, according as the succeeding cuts may be required to proceed to the right or to the left.

In fig. 1, Plate IX., the rod 51 and loose arm 52 are down, and the segment or rack 50 is up; but when the lever 13 is sent over like fig. 4, it will carry down the arm and rack 50. This, by causing the pinion to revolve, will bring up the lower arm 49, and thereby push up the connecting rod 51, which will lift up the arm 52; and the latter, by its spring-catch, will carry round the wheel 47 a given number of teeth; which quantity may be varied two ways, either by fixing the swivel nearer to the centre of the arm 52, or by placing the lower stud nearer to or farther from the centre of the arm 49. The long horizontal screw which is thus moved is left threaded; therefore this action just described will gradually move the cutting tools from the left to the right side; and on merely turning the catch on the arm 52 the other way, they would in like manner gradually proceed back. When the stud 12 makes the second alternation, by pushing the lever 13 back to its position in fig. 1, the connecting rod 51 will be lowered, and only bring back the spring-catch, because at the top of the wheel 47 is placed another spring-catch 53, which detains the wheel.

This arrangement of the connecting rods requires the back-cutter 46 to be on the left of 45, and to make the first cut in order, if they both cut in one plane; then 45 comes down at the return, and makes the second cut, at the end of which the wheel 47 is carried round enough to move the cutters over the width of two cuts; but if the connecting rod 51 was joined to the upper arm 49, the slide 41 would be moved when the other end of the work had passed the cutters, then the cutter 45 would have to precede 46; but if working in two planes, it matters not which cutter takes the precedence, only the first cutter must work in the upper plane, and the other follow some few cuts apart, as before stated.

In fig. 1, Plate X., is shewn the end view of a lathe-bed, firmly secured on the machine bed *k*, in the act of being cut, by its traversing longitudinally past the tool 45.

Having now got the machine at work, we may as well finish the description of the small parts before setting the machine for a different use. We must therefore return to that busy mover the lever 13, figs. 1, 4, and 5, Plate IX. It will be seen that the detents are strongest at the notches which hold the lever, and that they taper nearly to points a little beyond each other's notches, by which whilst the lever is held in one notch, the end of the other detent rests on it, and thus cannot by any possibility offer any resistance to the lever's return to its own notch; then it will be seen that the side of the notch in each against which the lever 13 falls is lower than the other; it is therefore an effectual stop, and always detains the lever exactly at the notch. Again, these lower sides form the slopes by which the studs 11 and 12 alternately lift the detents, but which neither of the studs can reach till they have pressed close the spring 20 on that side, and thus wound it up. We may now quit this lever, and go to the other or outer end of its axis, on which have been described the two arms 39 and 50. Opposite to the arm 39 is fixed another longer arm 54: this is shewn separate in fig. 9, and in place in fig. 5; its end only is seen in fig. 1, where it is joined by a connecting rod 55 to a lever 56, which turns on a stud in the standard *n*. By laying hold of the opposite end of this lever the workman can alternate the bed *k* whenever he has occasion, without using the studs 11 or 12; or he can, by holding it midway, stop the machine altogether.

In all cases it is requisite that the tool be withdrawn from the surface whilst that is returning for the next cut. Supposing the front cutter 45 is to operate on the right vertical side, the cross slide-bar 32 is then to be fixed by the screws 33 and 34 from moving, and the connecting rod 40 is to be removed; and the cutter must be advanced downwards, by the winch-handle 60, for each succeeding cut: in this case an alternating motion only of the horizontal slide-screw is to be used. Now, the stationary spring-catch 53 at the top of the wheel is turned up out of the way, as in fig. 10, Plate IX., and the catch on the loose arm 52 is put down on one side, as in fig. 11, and an opposite catch screwed to it, by which the arm 52 becomes fixed to the wheel, (figs. 10, 11, 13, and 14, are drawn twice the size to shew their different parts). In this case, the up and down motion of the long connecting rod 51 will only carry that side of the wheel up and down; and when, by the stud 11 or lever 56, the lever 13 is put over like fig. 4, the rod 51 will rise and move the wheel 47 and its screw; this, therefore, will move the tool to the right, and clear the work whilst it is coming forwards; the contrary alternation will lower the rod 51, and put the tool again close to the work for another cut. Next, if the left side is to be cut by the back tool 46, this same action will serve, but if the front cutter 45 is used, the bottom of the rod 51 must be connected with the opposite arm 49, and then it will serve. Thus, by changing the arms 49, either cutter may be used for either side. It must again be noticed, that when the studs 11 or 12 move the lever 13, they lift up the spring detents; the lever 56 has no provision for that purpose, therefore a pin is put in each detent, as shewn in figs. 4 and 5. An iron arm 57 projects from the standard *n*, to which one of the detents is attached, and on the flat top of this is laid a sliding plate with a handle 58, (see fig. 5); this plate slides under two screws that hold a spring down on it, and it has two inclined planes corresponding with the two pins of the detents. Fig. 12 is an edge view to shew the inclined planes 59 59; when the lever 56 is to be used, they are to be slid under the pins, in order to raise the detents just enough to let the lever 13 move to and fro, but not enough to let it pass the stops or lower sides of the notches.

Next, suppose the cutter operating on a horizontal surface: whilst the cross slide-bar 32 is fixed, the arm 52 is liberated by removing the extra catch in fig. 11 from it; the screw will again be caused to turn and advance the tool either to the right or left according as the spring-catches 52 and 53 are placed to the right or left; in this case the tool is to be raised by the screw-handle 60, to clear the work during its return; and in order to ensure the tool coming down again to exactly the same place, a stop 61 is fixed at top of the slide 44, and on the screw is placed a loose arm 62; this has a clipping screw by which it may be bound fast to the slide-screw. Whilst the cutting-tool is at the right depth, this arm is brought close to the stop 61, and then bound fast; the tool is now made to recede from the work by turning back the screw, and it is brought to it again correctly by again bringing the arm 62 close to the stop. Hitherto I have described the tool proceeding down a vertical side, or clearing of the level surface, by the close attention of the workman, who is obliged to keep time with the machine; but Mr. Clement has contrived to effect these purposes by some of the movements already described as proceeding from the lever 13. First, let the tool have to proceed downwards; the stop 61 and handle 60 are removed, and another arm 63 is put on and held fast by its clipping screw, as shewn in figs. 7, 8, and 9, in Plate X.; this arm has a spring-click at its end, (fig. 13 shews the arm and click separate); above this is placed a ratchet-wheel and pulley 64; this wheel has also a clip and screw to bind it on when required, but at present it is loose. If this pulley 64 is turned one way, it passes the click; but when it returns, it carries by means of the click the arm 63 and the screw round with it; this action lowers the tool; therefore, to obtain the alternations of this pulley, a spring-barrel 65 is mounted on the right standard, the circumference of which is a pulley wide enough to receive several coils of the gut-band 66. This band passes twice round the pulley 64, and then proceeds to the left side, where a pulley 67 is mounted to receive and change its direction. Both the spring-barrel 65 and pulley 67 are mounted on sliding plates, by which they may be placed and kept level with the pulley 64, even whilst that is at work, and consequently slowly descending, because the extra length of band required to let the pulley 67 descend will be given off the spring-barrel 65. From thence it passes over another pulley to find its way down to one of the arms 49, figs. 1 and 7, Plate IX., from whence the pulley 64 will obtain its alternations, returning one way without moving the screw, and then going the other, and moving the screw round the required quantity; and by fixing the double catch, fig. 10, Plate IX., to the wheel 47, the lateral receding of the tool to clear, and its advance to cut, will be obtained as before described.

Next, to obtain only the alternate raising and lowering of the tool to cut a horizontal surface, the pulley 64 is bound fast by its clip, and the stop 61 again put on. Now, the band 66 moving to the left will raise the tool, and when it goes to the right it will bring the arm 63 against the stop 61, and thereby lower the tool exactly to the same place; the loose arm 52 and single catch causing the tool to proceed laterally for each succeeding cut, as before described.

I have described these last actions as they would be applied to fig. 1; but in figs. 7 and 8 they are applied to a separate cross-bar 68, which is much longer than 32; and the sliding part is a complete thoroughfare, eight feet long, the slider 69 being two feet long, and having three circles of holes to attach the circular plate 43 with the slide 44 to different parts, as the work may require. The end view, fig. 8, Plate X., and section, fig. 11, shews the strong form of the slide-bar and its dovetail : the bar measures a foot either way. Fig. 8 shews the firm manner in which the slider 69 lays hold of the dovetail as by a double hook, and has the whole breadth of bearing from top to bottom. This bar 68 has no alternating motion : it is supported on separate standards *n′ n′*. The section, fig. 11, shews its thickness ; it is cast hollow at the back, but with sufficient number of bars or partitions to preserve its stiffness ; it can be raised or lowered by vertical screws similar to those in the first standards *n n* : it is placed correctly in front of the machine, fig. 1, so that the same bed *k* can travel under it ; this enables work to be executed that is too wide to pass the first standards. The band 66 passes over two pulleys, and comes down to one of the arms 49 ; whilst from the other arm 49 a similar band rises, and passing over two pulleys, comes down near the end 71 of the long screw, on which is placed a loose arm and wheel similar to 52 and 47. If the long screw is only to alternate, this arm is fixed to the wheel by the double catch, fig. 10, Plate IX., and the second band is attached to it with a weight hanging below ; or the band is attached to a long connecting rod, either 40 or 51 will do, and this rod being held in the swivel of the loose arm 52, its own weight will be sufficient to drop the arm, and when it is pulled up the wheel and its screw will be moved. Then, if a stop is put to receive the arm 52 on its descent, the long screw will always be detained at exactly the same place, and therefore truly return the cutting tool for each succeeding cut ; and bringing this second band down on the opposite side of the wheel, will clear the tool, or make it recede and return for the opposite side of the work.

I have now described, generally, the machine and its movements; but there are some of the details that require further description, to shew how they are made and put together, to ensure good holding and freedom from shake. I will, therefore, return to fig. 5, Plate X., one of the bearings of the slide bar 32. That bar having to support a cutter on either side, it is of consequence that the cap 72 be united to the other half very firmly: it will be seen that the inner or solid portion of the bearing would have contained much more than half the hole, but there are steps or recesses at top and bottom, which reduce that side to a true half; into these the cap 72 is fitted very correctly, consequently the screws have not to support it, but merely pull it close: by this mode of fitting it acts almost like a solid hole, and the tool on either side acts quite well. Next, in fig. 10 is shewn a section of the two ends of the bar 32, lying in their bearings, without the caps; this bar has large shoulders against the inside of the bearings, and a second smaller shoulder is turned on the right end, so as not to come perfectly through the bearing, and it has a collar 73 screwed against it by three screws—one is shewn at 74; this collar binds the bearing between itself and the larger shoulder of the bar 32 sufficiently tight to remove all end-shake. Next, the studs 36 are supported against the screws 33 or 34, as low as ordinary tools need project; therefore it is similar to bringing a rest quite close to the work.

Thus having secured the bar or prism 32 from all lateral and end-shake, it is requisite also to secure the long screw that passes through it. This screw has a solid flanch 75 at one end, which is partly sunk into the bar

32, and at the other end a collar 76 is put on; a screw-point projects through this collar into a slit in the screw, to allow its advance, but prevent its turning round; this is followed by a screwed nut 77, which is made tight enough to remove all end-shake. Next, having described the means of removing all end-shake of the nuts that traverse the long screws, in the reference to fig 5, it will be sufficient to say, that the strong nut of the slide 41 has exactly the same provision, as shewn in the section, fig. 6, Plate IX.; and indeed all the moving screws throughout the machine have this provision; and the further details of the upright slides 42 and 44 are so well given in Mr. Clement's paper in the 46th volume, as to require nothing more of them here. Therefore, if we trace the various fittings all through, from the cutting tool to the standards *n*, we shall find no room left for any giving way or yielding; then we must go on and trace the connexion from the standard *n* to the work. The next joint is the union of the feet of the standards to the base : these feet are half as wide as the machine, and meet close to each other in the middle, as shewn in Plate VIII. fig. 3, and in Plate X. fig. 1, at 78 ; and these two very strong and broad feet act as a whole one to each standard, because of the very strong connexion made at top by the flanched cylinder 28, which combines the strength of the two standards to support any pressure made against one; thus the standards and base are firmly united. The second joint in order is the wheels *ff* to the base *a a*: the extremities of their axis are three feet apart, whilst the table or bed *k* is but two feet high, and there are set or adjusting screws acting against the flat ends of the axis so as to forbid all end-shake; they have nuts on them to bind them fast. Fig. 12 is a section of one bearing *e*, to shew a peculiar under-cut recess in the ends of the axis, into which the ends of the set-screws enter: this under-cut always retains a little oil; and as the wheel slowly revolves, the oil keeps running down the flat surfaces, and thus lubricates the screw-ends; an oblique hole 87 is drilled, through which oil may be projected into the cavity: the screw-ends being flat involves no difficulty about their keeping mathematically in the line of the axis. These screws hold the axis tight with the least possible friction, and by these all the pairs of wheels are adjusted to be in a perfect right line before each other; so that the parallel bars *g g* fit close between the rims of them all, without any pinch or any spare room. The wheels are made very strong, and are strongly united by their axis, on which they are keyed, so as to move as one. The keys pass through the wheels and the axis, binding them quite tight against the shoulders; therefore, should they at any time require alteration, the shoulders may be turned so as to let them approach a little nearer, and then, by re-turning the inside of their rims, they may again be accurately fitted to the parallel bars. But strong as these wheels are, the bed never lies on less than three pairs of them, and the parallel under-rails *g g* fit very accurately between the outer rims of the wheels, so as to leave no room for lateral motion; and whatever difference can occur in the pressure to one side more than the other, is caused to the full at the first cut, and continues so throughout. The great weight of the bed contributes to keep all quiet, and leaves no room for any spring or vibration; and though the connexion between the work and the tool may be traced very round about, yet it is the same, and quite opposite on both sides, like two Cs opposed, thus CↃ; it is therefore very firm and free from vibration. The tool does not visibly drag behind its place of rest, therefore when it quits a corner or the margin of a perforation, it does not spring or jump and break off the angle, or cut deeper than enough; and when the tool meets the opposite margin, it does not hesitate or allow of being dragged back, but quietly commences its work; it therefore will plane surfaces full of perforations quite well (although that is very severe work for a cutter if it can spring back or away from the work); for the firmer the machine can be made, so much deeper or stronger may the cuts be made with safety to the tool. That this machine is very firm, is proved to be the fact by the continued excellence of its performance, with so little comparative labour; for the power of one man is sufficient to keep the whole in motion for ordinary work, though two are employed if it has to make long and full cuts both ways.

Having now described the machine as acting on the surface, or the right, or left, or on the vertical, or right angular sides of ordinary work with perfect firmness, I have to shew how such work is quite firmly held on the bed *k* without the least strain either of itself or of the bed, and then to shew the various provisions for adapting it to the most irregular kinds of work.

On each side of the bed *k*, through its whole length, there are wooden covers 70 70 screwed to the outside of each rail-bar *g g*; they hang over the rims of the wheels *ff*, so as to protect them from all dirt; also across the extreme ends of the rails *g g*, the wooden covers, and the racks *h h*, there are plate-iron ridges 79, about two inches high; these catch all dirt or cuttings that might otherwise fall off the bed on to the wheels, and oblige it to fall either to the inside or outside of them, and never on the wheels; the wheels are thus kept very clean, which it is quite necessary they should be. In the bed *k*, Plate VIII., fig. 4, are shewn sixteen perforations; these serve for any projecting parts of the work to pass through, and also afford a ready convenience of attaching the right angular chucks 80 80, which are made of various lengths and heights — parts of one pair are shewn in fig. 5; and in fig. 1, Plate X., is a pair in use. There are also rows of small square holes at different parts of the bed; these serve to receive T-headed square pins or bolts 81. Fig. 6 shews one separate; these being put into the bed *k*, near the ends of a mass to be planed, as in fig. 7, it may be adjusted and held fast by wedges between it and them, to lie exactly in the line of motion, or parallel with the bed.

The three principal motions of the machine are strictly at right angles with each other; namely, the direct motion of the horizontal bed *k*, the crossing slide-bar 32, and the vertical faces of the standards *n n*. If a large mass is required to be planed on all four sides strictly parallel, and at right angles with each other, the most eligible side to be first cut is laid uppermost, and supported in the best position; it may then be fixed by T-bolts and wedges 81, fig. 7; or if it has perforations, it may be held by the upright chucks 80; when that surface is finished, it is to be laid undermost on the bed and held fast, when the opposite side will be planed strictly parallel to the first: these two surfaces are now placed as sides, and held between one or two pairs of the perfectly rectangular, and therefore upright chucks 80. These chucks are full of holes for screw-bolts to pass through; and, being made in pairs, the holes of one correspond with those of the other: some of these holes can always be placed opposite the perforations, and the work be firmly bolted between them. This is done whilst the chucks lie flat on the bed; they therefore hold the two planed sides vertical, and give them a right angular surface to lie on without any strain of the bed, and to which these chucks are bound when the whole have been slid into the best position. When the third side is planed that is put undermost, and it is allowed to lie flat on the bed, and be also held by the chucks, and all four sides will be correct. Fig. 5 shews one of the clamping bars 82. They cross under some of the perforations in the bed, and, by gently easing the screws, or rather before they are bound quite tight, the whole may be moved about till it is correctly adjusted. Fig. 8 is a stud having a screw horizontally through it: several of these are provided, and they are made to fit the small square holes. When work is laid on the bed in a suitable position, some of these can be put into the near holes, and the work quickly placed or adjusted by them and held quite fast. Fig. 9 is a larger T-headed bolt: they are suited to be bound cross-ways in any part of the long central opening, to tighten or stop the work end-ways: a variety of these different fittings to the bed saves much time, for by them the most irregular forms may be well held on the bed.

Next, let a surface require planing whose continuity is interrupted by projecting portions, one part may be planed as close to the projection as the tool can approach, then the projection must be allowed to pass behind the tool; for this purpose it may be necessary to raise the cross slide-bar to let it pass, and if this could not be returned with certainty to the same place, the work would not be true: here we see the great importance of the nuts on the vertical screws, by which all loss of time or end-shake is prevented, so that the least turn of the screws will move the slide-bar. By having thus secured the accuracy of their performance, a micrometer-head may be trusted. Accordingly, the two bevel-wheels 24 at their heads have each 400 divisions on their circumference; the screws having two and a half threads in the inch, make each division equal one-thousandth part of an inch: by noting these divisions before raising the slide-bar 32, it may be returned with the utmost accuracy to its former place. The micrometer-heads of the vertical slide-rests 42 or 44 answer the same purpose for passing a longitudinal ridge, so that both sides may be in the same plane, because, of necessity, the slide-bar 32 must then be high enough to let the ridge pass, and therefore raising the tool is sufficient. The additional slide-bar, figs. 7 and 8, has been described as mounted on additional standards; but a similar thoroughfare slide-bar may be mounted at the back of the standards *n n*, and attached to the same vertical carriages *p p*, instead of the back plates *o o*, because both kinds are wanted, neither being a complete substitute for the other. When the oscillating slide-bar 32 is used, the cutter cannot traverse at once the whole width between the standard; that space will be minus the width of the sliders 41. The thoroughfare slide-bar allows the tool to traverse more than the opening between the standards, and is not only calculated to work on the widest surface that can pass through, but to make long cuts parallel with itself, or at right angles to the motions of the bed: for this purpose, as well as for the convenience of placing the wheel 47 at either side of the machine, both ends of the slide-bar screw are turned of exactly the same size, and they have fins to keep the wheel, or handle, that may be put on, from turning without the screw. When making the cross-cut, a band-wheel or winch-handle is put on, by which the tool is made to proceed parallel with the slide-bar; when the tool has to proceed downwards, it cannot be made to move from the work during its return, therefore a provision is added to the bed *k*, by which the workman moves the work away from the tool, and returns it exactly to the same place.

In Plate IX., figs. 1 and 5, and Plate X., fig. 1, is shewn the arm or bracket 57, projecting from the left standard *n*; on the outside of this a large screwed hole 83 is fixed, and the sliding plates 9 and 10, with their studs 11 12, are removed, and another plate, shewn only in fig. 5, with a strong arm 84 projecting from it, is put on. This carries a screw 85, secured from end-shake, that corresponds with the hole 83, and is made to enter it. By the handle of this the workman can move the bed any small quantity to and fro. Then, to secure the accurate return of the work each time, there are two pins projecting from the arm 84; these serve for stops similar to 61 on the slide-rest 44, and an arm similar to 62 is clipped tight on to the screw. Therefore, when the work is brought to the right place for the first cut by this screw, the cross-arm is brought to one of the stops and bound fast: the second stop saves time by limiting the motion of the screw. Thus, by the stop on the screw the work is always brought correctly to the same place, and the tool is lowered a given quantity by the micrometer-head for each cut. As the whole of the bed *k* can pass the cutters, enormously large work may be laid on it, and have the outside portions planed by this motion parallel with the thoroughfare slide-bar. This bar being fixed vertical, the sides operated on will be vertical; but cross-cuts may be made on surfaces sloped to any angle, by the moving slide-bar 32: in this case the descending studs 36 are removed, and a strom-arm or quadrant fixed at top, or one at each end, if requisite. These may be bound fast by screws to the standards *n n*, to fix the bar, and consequently the slider 44, at any angle in which it may be required to work. The outside of the circular plate 43 is also divided, by which the tool may be caused to descend laterally at any given angle, during longitudinal cuts, such as dovetail grooves, slides, &c. Again, from the plate 43 may be removed the slide 44, and a head containing a mandril put on: this will receive motion from a crossing band making a whole turn round its pulley; a movable frame containing a fly-wheel with various grooves being provided for this purpose. This mandril will hold drills or cutters of any required form, by which, from the various motions of the machine, hollows or recesses of all kinds may be truly cleaned out, and the bottoms made flat, or strictly level with any other part. Again, on the plate 43, or slider 41, may be mounted cutters suited to the teeth of large wheels; these are made to descend or ascend progressively by the wheels and pinions at top of the standards *n n*: the wheel 26 has a groove round it for a band, or it may be turned by the handle 27. In order to hold the wheels whose teeth are to be cut, there is a round hole 86 in the bed, (see figs. 2 and 4, Plate VIII.); this receives the axis of a dividing plate. This plate is much larger than the bed is wide, and has an under-ring, whose diameter is the width of the bed; this ring lies on the bed, and secures the correct moving of the plate, which is made strong enough to bear any sized wheel; and as it is only requisite fully to support the teeth or other parts whilst they are being cut, a suitable block is placed on the bed under those teeth, by which they are always perfectly supported against the cutter, let the rest of the wheel hang ever so much over the dividing plate; this dividing plate is moved by a tangent screw, also fixed to the bed. Thus a toothed wheel can scarcely be wanted bigger than this machine will cut, and give the most perfect form to the teeth. Then, by inclining the slide-bar 32 by its quadrants to any required angle, bevel-wheel teeth may be cut or trimmed ; of course, the cutter is kept in a line that would pass through the wheel's axis, and the lateral motion is given to the wheel, so that all the cuts may correctly tend towards its axis.

Again, the bed *k*, figs. 2 and 4, Plate VIII., has a perforation its whole length down the middle, except round the hole 86; this is planed perfectly straight, and parallel with the sides of the bed, so as to convert it into a perfect lathe-bed, either to hold centres, or a head with suitable mandril. This serves many valuable purposes: a cylinder may be held between two centres, and a groove cut its whole length, perfectly true, so as to receive a key to bind a wheel, or any other kind of work at any part; pinions may be cut, or cleaned out in every part, and of any length or size; indeed, it will do the work of a turning lathe, in a different way, for it may cut cylinders or cones so as at once to be quite straight, by making them turn the width of a cut each time; or by raising one centre higher than the other, cones of any taper may be cut. Solids or prisms of any angle may be cut, either by the longitudinal or lateral motion of the cutter; and, by making the work revolve, it may be turned as in any other lathe. Thus, here is a complete union of the *turning lathe* with the *planing machine* and *dividing engine*, by which very complicated work may be executed.

Again, for cutting large racks, the bed *k* is prepared to receive a strong screw of its own length. In the end-view of the bed *k*, Plate X., fig. 1, is shewn a hole in which there is already a number 82; this hole is a complete thoroughfare to the other end. Just within either end, as it may be convenient, is fixed a screw-hole, with a screw-nut, to save all loss of time, as before described: this receives a screw, whose other end is firmly supported on a suitable standard rising from the base, so as to turn without end-shake, and it has a micrometer-head; this makes it a linear dividing engine. Therefore, a suitable cutter attached under the slider 41, and made to revolve, will traverse with it across the rack, which is previously made fast lengthways on the bed *k*, and thus any sized rack, either small or great, may be made or trimmed with perfect truth.